

Model Specification for Rework of Aircraft Engine, Power Transmission, and Accessory/Auxiliary Ball and Roller Bearings

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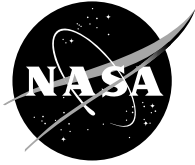
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Foreword

In the early jet engines of the 1950s, the primary limitation on their life and reliability was due to the rolling-element bearings supporting the engine main shaft. As engine technology advanced, so did the life and reliability of the ball and roller bearings that are integral components of these engines. The potential bearing lives from current technology are approximately 80 times that which could be achieved in the late 1950s. The price of these bearings has also risen significantly because of improved process and manufacturing costs related to their manufacture. In fact, the individual lives of these bearings can greatly exceed that of the engine for which they are designed. Consequently, it is feasible to reuse bearings after engine overhaul or refurbishment. The cost of bearing rework can be as low as 10 percent the cost of a new bearing, resulting in cost savings of as much as 90 percent that of a new bearing.

In late 1966, United Airlines contracted with Bearing Inspection, Inc. (Bii), to refurbish bearings for reuse in their commercial aircraft engines. In 1969, the U.S. Navy at North Island, California, began a bearing rework program for application in military aircraft engines. These methods of rework are what are now referred to as Levels I and II rework. In 1973, Israel Aircraft Industries (IAI) began Level II rework of jet engine bearings. Also in 1973, NASA Lewis Research Center (now NASA Glenn Research Center) in partnership with the U.S. Army Aviation System Command began a pilot program to establish Level III rework where bearing races are reground and new rolling elements (balls or rollers) are installed. Their study showed that as much as 90 percent of used bearings could be recovered and reworked.

Endurance testing of these bearings was successfully conducted to establish their reliability for aircraft applications. Based upon this early work, bearing rework has become a standard practice worldwide in the aircraft industry as well as in other commercial fields such as railways. The value of this business is on the order of hundreds of millions of dollars per year, with the resulting savings to the customer being many times this amount. The benefit to the environment is the recycling of bearing steels and critical alloys in addition to the energy costs associated with the manufacture of new bearings (i.e., steel processing, heat treating, and machining).

Analytical work published in 1977 by NASA Glenn Research Center compared the life of reworked inner races to that of brand new bearings. This work was expanded in 2005 to include rework of both the inner and outer races as well as the replacement of the bearing balls or rollers. Our work showed that the calculated lives of reworked and/or repaired bearings could range from 87 to 99 percent that of new bearings.

In 1982 a NASA, Army, industry committee was formed to write a model rolling-element bearing rework specification, which was subsequently published in 1985. This specification has formed the basis for bearing rework that is currently being performed in the aircraft engine industry. Although the specification is a guide to bearing rework, it is not a standard and thus is not necessarily followed by all those who perform bearing rework. Further,

there had been no effort to update the material and/or practices contained in the 1985 document. Because of the level of industry acceptance of bearing rework for aircraft application worldwide, the Federal Aviation Administration (FAA) has encouraged this activity to update the rework specification to reflect advances in manufacturing, repair, and general bearing technology. As the FAA guidance material for repairs evolves, the FAA is looking at potential incorporation of all or some portion of this material in the guidance material repair templates currently under development.

Model Specification for Rework of Aircraft Engine, Power Transmission, and Accessory/Auxiliary Ball and Roller Bearings

I. Preface

In commercial and military aircraft application, it has been a practice that rolling-element bearings removed at maintenance or overhaul be reworked and returned to service. Depending on the extent of rework and based upon theoretical analysis, representative life factors (LF) for bearings subjected to rework ranged from 0.87 to 0.99 the lives of new bearings. Based on bearing endurance data, 92 percent of the bearing sets that would be subjected to rework would result in L_{10} lives equaling and/or exceeding that predicted for new bearings. The remaining 8 percent of the bearings have the potential to achieve the analytically predicted life of new bearings when one of the rings is replaced at rework. The potential savings from bearing rework varies from 53 to 82 percent of that of new bearings depending on the cost, size, and complexity of the bearing.

The objective of this document is to provide a specification for rework and/or repair of bearings used in aircraft engines, helicopter main power train transmissions, and auxiliary bearings determined to be critical by virtue of performance, function, or availability. The rolling-element bearings to be processed under the provisions of this specification may be used bearings removed after service, unused bearings returned from the field, or certain rejected bearings returned for reinspection and salvage.

II. Background

Classical rolling-element fatigue, which is of subsurface origin, has been considered the prime life-limiting factor for rolling-element bearings. With proper design, handling, installation, lubrication, and system cleanliness, a rolling-element bearing will operate reliably until it eventually fails by fatigue. Field experience has shown that less than 10 percent of the bearings removed from service for cause have failed from end-of-life subsurface fatigue (ref. 1). The remaining 90 percent of the failures are due to causes such as lubricant flow interruption, lubricant contamination, lubricant deterioration, excessive dirt ingestion, improper bearing installation, incorrect mounting fits, mishandling of bearings prior to installation, installation of a contaminated bearing, manufacturing defects, ring growth in service due to metallurgical changes, and corrosion. These other modes of failure are for the most part unpredictable. Their origin tends to be of surface as opposed to subsurface. In general, failures due to surface defects occur much earlier than those due to classical rolling-element fatigue (refs. 2 to 4). As a result, in aircraft engine and drive train applications, a large number of bearings are discarded at overhaul or during periodic maintenance because of surface defects (ref. 5).

Typically, the total life of a commercial aircraft engine with repair can be expected to exceed 60 000 hr. In general, new-technology, first-run engines may get upward of 20 000 hr of operation before engine removal and refurbishment. Operating times for second-run engines after subsequent overhauls are less than those of first-run engines (ref. 6). Rolling-element bearing life L_5 for these engines can range from 30 000 to over 100 000 hr.

New bearings are usually designed for the anticipated life of the engine and are not dependent on the number of times the bearings are reworked. Usually, bearing failure by spalling is a cause for immediate engine removal. However, most damaged bearings are discovered because the engine was removed for other causes and the damage was identified during the rework process.

When a raceway is damaged by fatigue spalling, it is not repairable and the whole bearing may be rejected. However, if the mating race is not damaged, the damaged raceway may be replaced to render the bearing reusable and fit for its intended purpose, if allowed by applicable procedures.

It has been a practice in commercial and military aircraft applications that rolling-element bearings removed at maintenance or overhaul be reclaimed. Bearings are disassembled, cleaned, and visually inspected. If no significant imperfections are found, the bearings are reassembled, lubricated, and packaged for further service. In some cases, the rolling elements are replaced with new balls or rollers (ref. 7).

Bearing refurbishment and bearing restoration, which are extensions of bearing reclamation, entail the following: honing (i.e., superfinishing) or grinding the raceways; restoration of critical bearing surfaces to regain their original characteristics and dimensions; and replacing the rolling elements with new ones (refs. 8 and 9). Honing restores the raceway finish to its original or to an improved condition and removes superficial surface defects (debris dents, pits, scratches, corrosion, etc.) that would potentially reduce the bearing life. During refurbishment, only 2.5 to 12.7 μm (0.0001 to 0.0005 in.) of parent raceway material is removed by honing. At each overhaul, the rolling elements are replaced with a new set.

The process of bearing restoration by grinding was first reported in 1976 (refs. 8 to 10). If superficial but rejectable surface damage to the bearing raceways has been caused by dirt or debris, raceways can often be restored by grinding. In general, superficial damage extends less than 50 μm (0.002 in.) starting at the surface.

To experimentally establish the reliability of the restoration process, a pilot program comprising 250 rolling-element bearings from three separate bearing types that had been removed from service at maintenance were subjected to the bearing restoration process (ref. 9). Of this number, 30 bearings from each type were endurance tested for 1600 hr at design loads. All the bearings had their rolling-element sets replaced with new ones. There was no occurrence of bearing failure that was related to material removal from the raceways. Two bearings failed because new rolling elements were defective (refs. 5 and 9).

In 1982 the U.S. Army Troop Support and Aviation Material Readiness Command (TSARCOM) in St. Louis, Missouri, requested that the NASA Lewis Research Center (now Glenn Research Center) organize a broad industry committee to improve both the reliability and availability of ball and cylindrical rolling-element bearings used in U.S. Army aircraft. A NASA, Army, industry committee was formed, comprising 37 persons representing 25 companies and U.S. government organizations. These included helicopter companies, bearing manufacturers that supply bearings to the U.S. Army Aviation Command, and aircraft engine manufacturers (refs. 11 and 12).

To improve bearing availability (and aircraft readiness), the committee prepared a bearing restoration and refurbishment specification. Bearing restoration refers to regrinding used bearings to new bearing tolerances and replacing the rolling elements. Bearing refurbishment refers to cleaning and inspecting bearings and fitting them with new rolling elements with the option to hone the bearing raceways. This bearing rework specification was based on previous work on bearing refurbishment and restoration performed by NASA Lewis Research Center and the U.S. Army Research and Development Command (refs. 8 to 10).

According to a theoretical equation derived by Coy, Zaretsky, and Cowgill (ref. 13) in 1977, the ratio of the L_{10} life of refurbished and restored bearings to the L_{10} life of brand new bearings results in the life factors for bearings initially removed from service at their theoretical L_{10} and L_{50} lives, respectively. The work of Coy, Zaretsky, and Cowgill was limited to the inner bearing ring life. In 2005, Zaretsky and Branzai (ref. 14) expanded this analysis to include the life of all the bearing components (inner and outer rings and rolling elements). In general, depending on the extent of rework and/or repair, the calculated lives of the reworked and/or repaired bearings will range from 87 to 99 percent the lives calculated for new bearings. Based on bearing endurance data, 92 percent of the bearing sets that would be subjected to rework would result in L_{10} lives equaling and/or exceeding those predicted for new bearings, with the remaining 8 percent having the potential to achieve the analytically predicted life of new bearings when one of the rings is replaced at rework. The potential savings from bearing rework varies from 53 to 82 percent that of new bearings depending on the cost, size, and complexity of the bearing.

III. Specification

1. Scope – This specification shall provide for the optimized utilization of aircraft engine, helicopter main power train transmission, and auxiliary bearings determined to be critical by virtue of performance, function, or availability.
 - 1.1 Sources: Those bearings to be processed under the provisions of this specification may be used bearings removed after service, unused bearings returned from the field, or rejected bearings returned for reinspection and salvage.
2. Applicable Documents – See section IV entitled “Documents, Standards, and Procedures” herein below for general specifications, standards, and other supporting documentation. In addition, the following will apply:
 - (a) NAVAIR 01–1A–503 U.S. Navy Bearing Manual
(TM 55–1500–322–24)
 - (b) NAVAIR 02–01–517 U.S. Navy Standard Maintenance
Procedures for Pratt & Whitney Aircraft Engines
3. Qualification and/or Certification – Sources for bearing rework must be qualified by the original contractor or the cognizant government agency by dynamic testing of a sample of reworked bearings for life and/or performance and/or quality audit.
 - 3.1 Qualification: In lieu of testing of the specific bearing design being processed, qualification may be based on prior evaluation of another bearing size of similar material, type, and family produced by the same source using continued unchanged processes.
 - 3.2 Certification: Bearings reworked to an improved standard shall be certified for use using an approved/specific form and permanently marked to indicate name of procurement agency as well as all other markings required to ensure traceability.
4. Requalification Requirements – On those bearings for which a new facility is to be utilized or for which a significant¹ process or design change is intended, requalification is required. The cognizant government authority may conduct or oversee the qualification by testing and/or quality audit or may delegate this responsibility.
5. Recertification Requirements – For those bearing designs which a qualified shop has not reworked for 4 years or more, recertification of the process for that bearing design by the original/prime contractor is required. As an alternative, the cognizant government authority may perform or delegate the recertification.
6. Process – The rework process will, in general, proceed in accordance with the bearing rework processes chart (fig. 1).
7. Inspection – Inspection of assemblies and components shall be conducted in accordance with negotiated quality plans, which shall include record requirements.
 - 7.1 Inspection Details: First article inspection details shall be recorded and maintained as a permanent record. Subsequent inspection requirements shall be per the quality plan.

¹Significant process change is defined as any deviation from previous approved practice and/or those processes that deviate from those specified from the rework process chart (fig. 1).

8. Rejection – All components and assemblies that are rejected shall be identified and held for quality/material review board action. Those components that may be reworked shall be rerouted at the discretion of the rework manufacturer, provided that the original drawing requirements or approved inspection criteria are met. Assemblies may be reworked, dismantled, and reassembled if this is accomplished in accordance with a negotiated quality control plan.

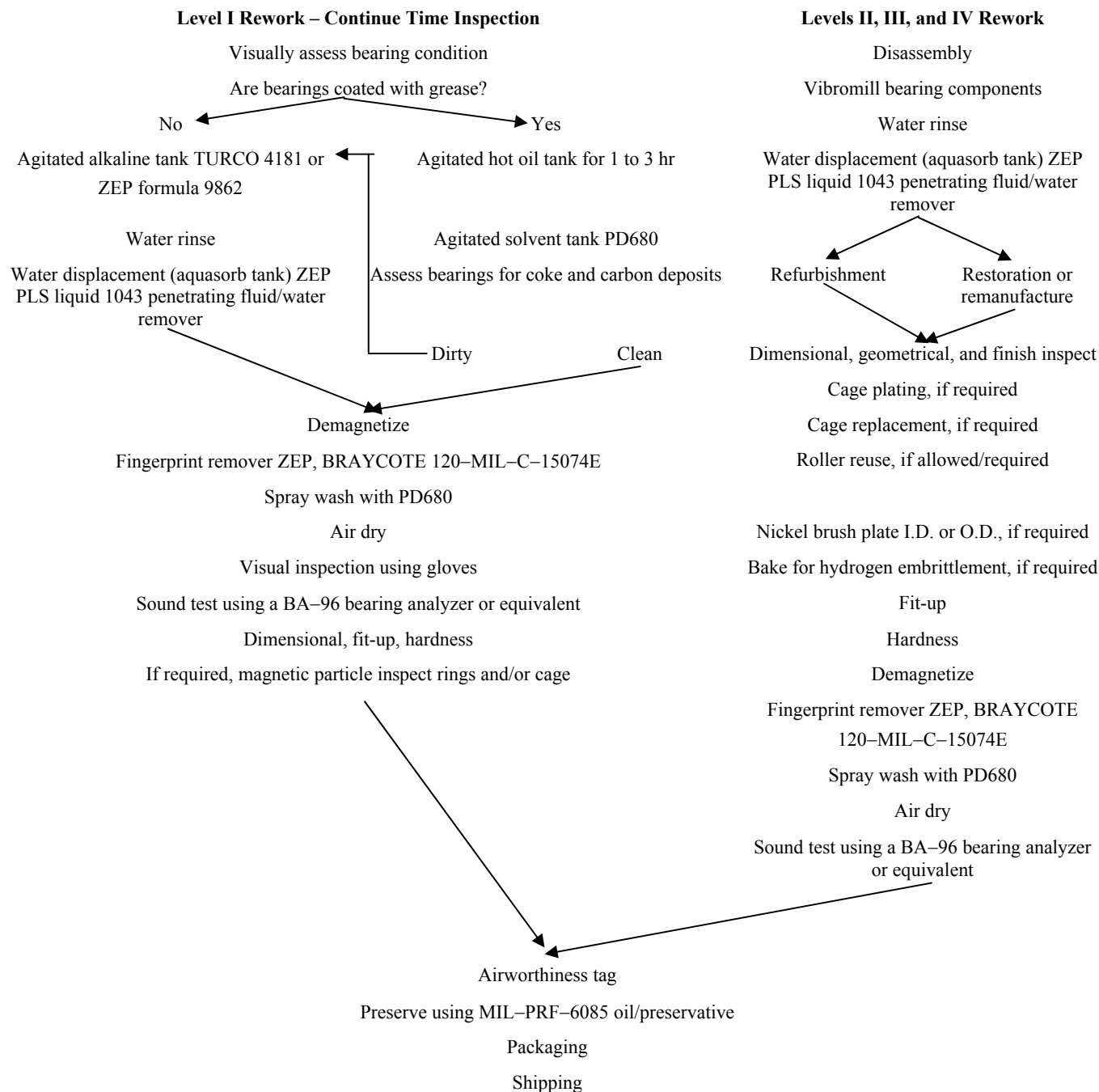


Figure 1.—Bearing rework process chart.

9. Change Control – There shall be no change to the original design, material, tolerances, basic processes, quality control plan, or heat-treatment, postheat-treatment, or rework procedures without prior approval of the original contractor or the cognizant government authority.
- 9.1 Change Control Approval: Any request for change shall be the responsibility of the vendor to submit prior to the initiation of work on the contract.
10. Process and Inspection Approval – After award of the production contract, all process operations and inspection procedures will be evaluated and confirmed by the cognizant government authority or his delegated representative to ensure compliance with currently accepted aerospace industry standards. This will include all destructive and nondestructive methods and quality control plans and inspection methods.
- 10.1 Process and Inspection Changes: These shall be requested and approval pursued as stated in paragraph 7 herein above.
- 10.2 Process and Inspection Deviation Approval: These shall be requested and approval pursued as stated in paragraph 7 herein above, with the exception that process may continue, verbal approval having been granted. It shall be the responsibility of the vendor to provide documentation of each such instance.
11. Definitions – See glossary (appendix A).
12. Rework Process – Bearing rework is divided into four categories: reclamation, refurbishment, restoration, and remanufacturing. The operations will be conducted as detailed in NAVAIR 01-1A-503 U.S. Navy Bearing Manual (TM 55-1500-322-24) and as further specified in this document. The basic procedure is illustrated in figure 1.
- 12.1 Level I – Reclamation: Reclamation of bearings involves inspecting a used bearing, checking and comparing it with new bearing data or reverse-engineered data requirements. This process involves the following:
- a. Demagnetization
 - b. Cleaning
 - c. Nondestructive testing
 - d. Visual/microscopic inspection
 - e. Minor repair: buffing and polishing of inactive and active surfaces, polishing (using a fine grit stone) of nicks and gouges in inactive corner radii
 - f. Dimensional inspection.
 - g. Reassembly (to include retainer riveting or snap-in retention)
 - h. Dynamic testing (if required): rotation of bearing rings to permit evaluation of noise level, torque characteristics, and/or similar functional parameters
 - i. Lubrication/preservation: as covered in the purchase order
 - j. Packaging: as covered in the purchase order
- 12.2 Level II – Refurbishment: Refurbishment of bearings is rework of bearings that goes beyond the scope of reclamation (per section 10.1, Level I). This encompasses all of the operations of processing plus one or more of the following:
- a. Replacing rolling elements
 - b. Reworking or replacing retainers
 - c. Interchanging used components and/or substituting new components to create a different assembly identity

- d. Grinding or polishing and/or plating mounting surfaces as necessary to return to original drawing dimensions.
- e. Honing (superfinishing) raceways (not to exceed 0.0005 in. (12.5 μm) total metal removal per surface).

12.3 Level III – Restoration: Restoration of bearings involves the removal of material by a grinding operation. This term encompasses all the operations of reclamation (per section 10.1, Level 1) and refurbishment (per section 10.2, Level II) plus one or more of the following operations:

- 12.3.1 Grinding the inner and/or outer raceways as required to a depth of at least 0.002 in. (50 μm) but not more than 0.003 in. (75 μm), which removes all superficial damage and a large portion of the fatigue-damaged stressed volume. The inner and outer raceways guide flanges may be ground to depths equal to but not greater than that of their respective raceway.
- 12.3.2 Installing oversized rolling elements to maintain the original internal clearance in the bearing. The limiting ball or roller size shall be that necessary to maintain minimum retainer (cage)/ball or roller clearances.
- 12.3.3 Installing original or replacement retainer (cage) when required. The original minimum retainer (cage)/rolling-element pocket clearance and the maximum retainer (cage)/ring-land clearance shall be maintained as per original equipment manufacturer (OEM) drawings and/or specifications.

12.4 Level IV – Remanufacture: Remanufacturing of bearings involves rework of bearings, where new components beyond the rolling elements and retainers are manufactured. This term encompasses all the operations of processing and may involve either refurbishing or regrounding the old parts that are reused and one or more of the following:

- a. Manufacturing or OEM procurement of a new ring
- b. Manufacturing or OEM procurement of a new retainer (cage)

12.5 Additional Methods or Operations may be substituted for those noted in NAVAIR 01-1A-503 U.S. Navy Bearing Manual (TM 55-1500-322-24) if approved by the original contractor or the cognizant government authority.

12.6 Identification: To maintain traceability, in all cases the bearing rings and cages will carry permanent marking including original identification as well as the bearing rework contractor and date of completion for all successive reworks.

13. Number of Repairs – Unless specifically specified by OEM or restricted by maximum raceway stock removal or a maximum pitch diameter (on a print), the maximum numbers of repairs are as follows:

13.1 For Level I Repair: The number of reclamations is unlimited. However, after each repair the resulting bearing life is reduced from that of a new or unused bearing. The number of repairs should be governed by what may be considered an acceptable life reduction based on the specific application and operating profile.

13.2 For Level II Repair: The number of refurbishments/overhauls is limited by the ball or roller diameter used to compensate for raceway material removal. During refurbishment, a 0.0001- to 0.0003-in. (2.5- to 7.5- μm) layer of material is removed through raceway honing (superfinishing). At each refurbishment, new rolling elements (balls or rollers) are inserted. Based on the material removal, the new rolling elements (balls or rollers) should be up to 0.0006 in. (15 μm) larger in diameter than the previous ones in order to maintain the original bearing fit-up parameters.

13.3 For Level III Repair: The number of restorations shall not exceed one (1).

13.4 For Level IV Repair: The number of remanufactures should be governed by what may be considered an acceptable bearing life based on the specific application and operating profile but should not exceed four (4) times.

13.5 For Levels II to IV Repair

13.5.1 The number of repairs should be governed by what may be considered an acceptable bearing life reduction based on the specific application and operating profile and the amount of material removed from the respective raceways. The total material removed from a raceway when the contribution from all repairs and restoration are summed should not exceed a depth of 0.003 in. (75 μm).

13.5.2 For carburized steels, the total material removed shall not exceed a depth of 0.003 in. (76 μm) or a depth to assure that the case thickness is twice the depth of the maximum shearing stress under maximum bearing loading.

13.5.3 The limiting ball or roller size shall be that necessary to maintain minimum retainer (cage)/ball or roller pocket clearances as specified in the original OEM drawings and/or specifications. However, the replacement balls or rollers shall not be more than 0.004 in. (100 μm) in diameter and (for rollers) length than the standard OEM reference size.

14. Bearings having difficult-to-disassemble retainer (cage)-roller sets and requiring the removal of retainer rivets or the temporary distortion of roller retention features (tabs or tangs) may be reassembled by installing new rivets or rebending the retention features.

15. Preservation and packaging shall be provided in accordance with the original purchase order, unless specified otherwise.

16. Issue and storage shall be in accordance with NAVAIR 01-1A-503 U.S. Navy Bearing Manual (TM 55-1500-322-24) when the required qualification has been accomplished. Follow-on lots shall be released for use in accordance with the purchase order.

IV. Documents, Standards, and Procedures

1. Dimensional Requirements

1.1 Bearing Manufacturing/Detailed Drawing Exists

1.1.1 Restore drawing requirements

1.2 Drawing to be created by reverse engineering of new bearings

1.2.1 Number of bearings to be measured: Five (5) minimum

1.2.2 Drawing tolerances to be set according to ANSI/ABMA (American National Standards Institute, Inc./American Bearing Manufacturers Association and/or ISO Standards

American National Standards Institute, Inc./American Bearing Manufacturers Association
(ANSI/ABMA), Standards for Ball and Roller Bearings and Balls

- Standard 1: Terminology for Anti-Friction Ball and Roller Bearings and Parts
- Standard 4: Tolerance Definitions and Gauging Practices for Ball and Roller Bearings
- Standard 10: Metal Balls
- Standard 12.1: Instrument Ball Bearings – Metric Design
- Standard 12.2: Instrument Ball Bearings – Inch Design
- Standard 16.1: Airframe Ball, Roller and Needle Roller Bearings – Metric Design
- Standard 16.2: Airframe Ball, Roller and Needle Roller Bearings – Inch Design
- Standard 17: Needle Roller – Metric Design
- Standard 18.1: Needle Roller Bearings – Radial, Metric Design
- Standard 18.1: Needle Roller Bearings – Radial, Inch Design
- Standard 19.1: Tapered Roller Bearings – Radial, Metric Design
- Standard 19.2: Tapered Roller Bearings – Radial, Inch Design
- Standard 20: Radial Bearings of Ball, Cylindrical Roller and Spherical Roller Types, Metric Design
- Standard 21.1: Thrust Needle Roller and Cage Assemblies and Thrust Washers – Metric Design
- Standard 21.2: Thrust Needle Roller and Cage Assemblies and Thrust Washers – Inch Design
- Standard 22.1: Spherical Plain Radial Bearings, Joint Type – Metric Design
- Standard 22.2: Spherical Plain Radial Bearings, Joint Type – Inch Design
- Standard 23.2: Thrust Bearings of Tapered Roller Type – Inch Design
- Standard 24.1: Thrust Bearings of Ball and Cylindrical Roller and Spherical Roller Types – Metric Design
- Standard 24.2: Thrust Bearings of Ball and Cylindrical Roller and Spherical Roller Types – Inch Design
- Standard 25.2: Roller Bearings, Linear Motion Recirculating Ball, Sleeve Type – Inch Series
- Standard 26.2: Thin Section Ball Bearings – Inch Design

ISO – International Standards

- ISO 492: Rolling Bearings, Radial Bearings, Tolerances
- ISO 5735: Rolling Bearings, Radial Internal Clearance
- ISO 15: Rolling Bearings, Radial Bearings, Boundary Dimensions, General Plan
- ISO 582: Rolling Bearings, Chamfer Dimensions, Maximum Values

Other ISO Standards as applicable

1.3 Critical Dimensions

- 1.3.1 Boundary dimensions: Inside diameter (I.D.), outside diameter (O.D.), width. In the case of specially design bearings, other dimensions, such as flange dimensions, lock-ring size location, oil holes size and location, et cetera., shall be considered.
- 1.3.2 Fit-up dimensions: Radial play (internal clearance), axial play, contact angle, flushness (face protrusion). Also, if the bearings are assembled in pairs (e.g., duplex back-to-back, DB; duplex face-to-face, DF; tandem, DT), the fit-up dimensions for staking shall be considered.
- 1.3.3 Geometrical dimensions: Inner and outer runout (assembled bearings), inner and outer corner radii and maximum breakouts (axial/radial)

- 1.3.4 Assembly dimensions: Roller bearing retainer tab to roller outside diameter clearance, maximum allowed rivet head diameter height

1.4 Critical Characteristics

- 1.4.1 Internal geometry: Raceway radial roundness, raceway waviness, raceway curvature, raceway straightness (roller bearings), ring wall thickness, raceway shoulder height, bearing-to-cage face clearance, diametrical cage land clearance (at inner and at outer), relieved shoulder height (for angular contact thrust ball bearings), ball grade, roller profile control parameters (crown drop, gage point, cylindrical length, cylindricity, and end profile)
- 1.4.2 Finish: Faces, O.D., I.D., raceways, ring pilot surface, cage pilot surface, cage pocket prior to plating, roller O.D., roller ends

1.5 Process Specific

- 1.5.1 Material: AISI and AMS specification. Material shall be identified by chemical analysis with listing of constituents accompanied by inclusions count and qualified for a specific AMS specification.
- 1.5.2 Static and dynamic loads
- 1.5.3 Operating temperature
- 1.5.4 Nondestructive testing: Magnetic particle, nital etch, eddy current, fluorescent penetrant, and visual inspection, as applicable
- 1.5.5 Residual magnetism
- 1.5.6 Material and processes traceability records

1.6 Cage Reverse Engineering

- 1.6.1 Cage dimensions: Cage dimensions for design and manufacturing shall be determined by calculating the average from measurements of at least 10 cages taken from a minimum of 5 different serviceable or new bearings of the same part number. If necessary, silver-plated cages can be stripped prior to measurements.
- 1.6.2 Radius or chamfer: Unless otherwise specified, inside corner radius or chamfer shall be 0.020 to 0.050 in. (500 to 1270 μm) maximum; outside corner radius or chamfer shall be 0.010 to 0.025 in. (250 to 635 μm) maximum except at the
 - (a) Junction of the cage pockets and the cage I.D. and O.D. on phenolic cages
 - (b) Corner formed by a rivet head counterbore and a cage face, which shall be 0.010 in. (250 μm)
- 1.6.3 Retention: Ball and roller retention devices shall not restrict normal operation of balls and rollers.
- 1.6.4 Mismatch on two-piece cage: Radial and circumferential mismatch between cage halves shall not exceed 0.004 in. (100 μm). Radial mismatch applies on cage guiding diameter only.

- 1.6.5 Silver plating: When specified, cages shall be silver plated to thickness of 0.001 to 0.002 in. (25 to 50 μm). Bronze cages shall be plated in accordance with AMS 2412 and steel cages shall be plated in accordance with either AMS 2412 (low-bake plating) or AMS 2410 (high-bake plating), as applicable. The silver-plate thickness requirements apply to all functional contact surfaces. Corner buildup maximum is 0.0025 in. (64 μm). Retainers (cages) with plating that exceeds the maximum thickness limit shall not be used.
- 1.6.6 Cage face-to-bearing face clearance: With bearing end play and cage end play removed (yielding minimum cage-to-face clearance), the minimum clearance between each cage face (including rivet heads) and the adjoining bearing ring faces shall not be less than 0.001 in. (25 μm).
- 1.6.7 Cage pocket position: Cage pocket axes shall be in the same plane within a single tolerance zone formed by two parallel planes that are spaced 0.004 in. (100 μm) apart. On land-guided cages, each pocket axis shall be perpendicular to and intersect with the guiding-diameter axes within a diameter tolerance equal to 0.001 times the cage pilot diameter.
- 1.6.8 Land-guided machined metal cages: On land-guided machined metal cages, all rolling-element pockets shall be equally spaced circumferentially within the limits given in table 1.

TABLE 1.—CAGE SINGLE-POCKET SPACING

Guiding land diameter, ^a in. (m)	Circumferential spacing tolerance (max.), ^b in. (μm)
Up through 2.0 (0.05)	0.002 (50)
2.1 (0.05) through 3.0 (0.08)	0.003 (75)
3.1 (0.08) through 4.0 (0.10)	0.004 (100)
4.1 (0.10) and larger	0.005 (125)

^aNominal.

^bThe limits apply for single pocket against design location tolerance, not total of errors around retainer (cage).

- 1.6.9 Cage-to-ring radial clearance: On ball/roller-guided cage-type bearings, the radial clearance between the cage and the rings shall not be less than 2 percent of the ball/roller diameter when the cage play is removed in any direction.
- 1.6.10 Cage roundness: On land-guided machined metal cages, the guide diameter shall be round within 0.004 in. (100 μm) on 20- through 40-mm bore bearings; 0.006 in. (150 μm) on larger than 40-mm bore bearings; and 0.002 in. (50 μm) on smaller than 20-mm bore bearings. This roundness tolerance applies as the difference in radius between two concentric circles and corresponds to a total indicator reading taken when the cage is rotated on the guided diameter axis.
- 1.6.11 Cage-guided diameter waviness: On silver-plated, land-guided, machined metal cages, the guide diameter shall be free of repeating lobes greater than the minimum plating thickness for a lobe angle equal to the angle between pockets.
- 1.6.12 Dynamic balancing: For main engine bearings and bearings operating at high speed, machined metal cages shall be dynamically balanced, matched, and aligned by serial number, within the limits as specified in ISO 1940 and ANSI S2.19 Quality Grade G–6.3. Material may be removed for balancing purposes only from outside face surfaces using chordal cuts. No base material is allowed to be removed unless specifically allowed by OEM. All balancing cuts must fair smoothly and be finished to within 63 in. (1.6 μm) Ra (arithmetic av). Break all sharp edges 0.005 to 0.010 in. (125 to 250 μm).
- 1.6.13 Inside tang corner radius: Machined metal cages, tang design, shall have a minimum 0.012-in. (305- μm) radius between tangs in the circumferential direction.

- 1.6.14 Concentricity: Machined cages inside diameter and outside diameter shall be concentric to guide surface within 0.005 in. (127 μm); over/under tang diameter shall be concentric within 0.005 in. (120 μm) before bending.
- 1.6.15 Face parallelism: Machined cages faces shall be flat and parallel within 0.002 in. (50 μm).
- 1.6.16 Pocket corner radius: Machined roller bearing cages shall have a pocket corner smaller than roller corner radius in all four places.
- 1.6.17 Pocket surfaces: All pocket surfaces in axial direction shall be coplanar within 0.003 in. (75 μm).
- 1.6.18 Pocket sides parallel to cage face and to each other: Machined roller cages shall have pocket sides parallel to cage face and to each other within 0.004 in. (100 μm).
- 1.6.19 Pocket position: Machined cages shall have pockets symmetrically centered on cage width within 0.005 in. (125 μm).
- 1.6.20 Cage face flatness: Machined cages shall have faces flat within 0.002 in. (50 μm) for cages with O.D. up to 4 in. (0.1 m) and 0.003 in. (0.1 m) for cages with O.D. larger than 4 in. (0.1 m).
- 1.6.21 Pocket perpendicularity to cage face: Pocket sides shall be perpendicular to cage face within 0.002 in. (50 μm) for cages with O.D. up to 4 in. (0.1 m) and 0.003 in. (75 μm) for cages with O.D. larger than 4 in. (0.1 m).
- 1.6.22 Cage face perpendicularity: Cage face perpendicularity (squareness) to cage I.D. or O.D. shall be within 0.002 in. (50 μm).
- 1.6.23 Roller retention of cage: The roller retention feature of the cage shall be either a one-tab or a two-tab machined or staked design depending on the roller length. For machined tabs, each tab shall be cut through in the axial direction to form two wings for bending. The purpose of such design is to ensure that the wings of the tabs can be straightened and reformed without any damage during assembly/disassembly. Retainers with a staked (swaged) tan/tang design shall not be reused; they usually permanently deform during disassembly. For high-speed bearings, the recommended design is staked.

1.7 Roller Reverse Engineering

- 1.7.1 Roller nominal diameter (basic size) shall be determined by calculating the average diameter from measurements of at least 10 rollers each taken from a minimum of 5 different serviceable or new bearings of the same part number. Nominal diameter shall be the nearest tenth of a millimeter number (e.g., 5 mm, 7 mm, 8.1 mm, etc.).
- 1.7.2 Maximum oversized diameter (over roller nominal diameter or basic size) shall not exceed that necessary to maintain minimum retainer (cage)/ ball or roller pocket clearances as specified in the original OEM drawings and/or specifications. However, the replacement balls or rollers shall not be 0.004 in. (100 μm) greater in diameter and (for rollers) length than the standard or reference size.
- 1.7.3 Roller cylindricity shall be as indicated in table 2.

TABLE 2.—ROLLER CYLINDRICITY

Cylindricity	RBEC grades 1 and 3, in. (μm)	RBEC grades 5 and 7, in. (μm)
Roller up to 0.5000-in. (12.5-μm) diameter	±0.00005 (1.25)	±0.00003 (0.75)
Roller over 0.5000-in. (12.5-μm) diameter	±0.00006 (1.5)	±0.00003 (0.75)

1.7.4 Roller cylindrical length (effective length) and roller crown drop (at crown gage location) shall be determined by tracing, using linear equipment (e.g., Federal Surfanalyzer 5000 System) with appropriate software or equivalent, at least five (5) rollers taken from used reworkable bearings. Crown gage location shall be calculated and centered on the distance between junctions of corner breaks and crown surfaces. The crown gage location value shall be rounded to the nearest hundred of a millimeter number (0.75 mm, 1.0 mm, 1.25 mm, 2.0 mm, etc.)

1.7.5 Roller cylindrical length shall be centered on roller entire length within 0.020 in. (500 μm).

1.7.6 Roller crown drop limits shall not exceed 0.0002 in. (5 μm) for rollers with diameters smaller than 0.39 in. (0.01 m), and 0.0003 in. (7.6 μm) for rollers with diameters larger than 0.39 in. (0.01 m).

1.7.7 Roller crown radius shall be calculated with the following formula:

$$R = \frac{(L_2^2 + L_1^2)}{8} \times H$$

Where

R crown radius
 L_2 gage point location to gage point location (roller length – 2 × gage point location)
 L_1 average cylindrical length
 H average crown drop

All dimensions are in inches, meters, millimeters, or micrometers.

1.7.8 Transition from cylinder surface to crown surface must be smooth.

1.7.9 Visual appearance of crown surface must conform to visual appearance of cylindrical and end surfaces.

1.7.10 Roller nominal length shall be determined by measuring at least 10 rollers each taken from new and/or used reworkable bearings. Nominal length shall be to the nearest tenth of a millimeter (e.g., 5 mm, 7 mm, 8.1 mm, etc.).

1.7.11 The length of any roller shall not depart by more than plus or minus 0.0001 in. (2.5 μm) from nominal. The effect of out of squareness of the end face shall lie within this tolerance.

1.7.12 The maximum departure from squareness to diameter of either end face of any roller shall not exceed 0.0001 in. (2.5 μm).

1.7.13 Roller ends shall be parallel to each other within 0.0001 in. (2.5 μm).

- 1.7.14 Roller corner breaks shall be determined by measuring a minimum of five (5) each rollers taken from five (5) used reworkable bearings. The nominal corner break shall be the nearest tenth of a millimeter value (0.4 mm, 0.5 mm, etc.). Maximum limit shall be 10 percent larger than the nominal, and the minimum limit shall be 10 percent smaller than the nominal.
- 1.7.15 The blend of cylindrical surface to crowned portion and corner of all rollers shall be a smooth continuous curve. The blend form will be as produced by Supfina honing or a similar process approved by the original contractor or the cognizant government agency.
- 1.7.16 Roller corner radius limits shall be established as follows: the minimum value equal to the maximum roller corner break; the maximum value equal to five times the minimum value. Numbers shall be rounded up to the nearest whole number. The interpretation of the minimum and maximum values of fillet radii is as shown in ANSI Standard Y14.5M, section 2.15.2, and in figures 2 through 19 thereof.
- 1.7.17 Roller corner runout shall not exceed 0.001 in. (25 μ m).
- 1.7.18 Rolling-element surface finishes shall be equal to or better than those specified in the original OEM drawings and/or specifications and/or measured from a minimum of five (5) rollers each taken from five (5) new and/or used reworkable bearings.

2. Conditions for Rework of Used Flight-Worthy Bearings

- 2.1 Nondestructive Inspection Requirement to Detect Subsurface Damage: Eddy current, ultrasonic, magnetic particle, and magnetic perturbation techniques may be used to inspect and detect subsurface flaws and cracks in used bearings.
- 2.2 Reclamation: A used bearing can be found airworthy and returned to service through a Level I rework process called reclamation. The reclamation process involves but is not limited to the following:
 - a. Demagnetization
 - b. Cleaning
 - c. Nondestructive testing
 - d. Visual/microscopic inspection
 - e. Minor repair: buffing and polishing of inactive and active surfaces; stoning of nicks and gouges in corner radii
 - f. Dimensional inspection
 - g. Reassembly (to include retainer riveting or snap-in retention)
 - h. Dynamic testing (if required); rotation of bearing rings to permit evaluation of noise level, torque characteristics, and/or similar functional parameters
 - i. Lubricant/preservation: per requirements covered in the purchase order
 - j. Packaging: per requirements covered in the purchase order

2.3 Refurbishing and Restoration of Raceways: Levels II and III Rework

- 2.3.1 Through- (case-through) hardened rings and surface (case-hardened) rings
- 2.3.2 Depth of honing: 0.0005 in. (12.5 μ m) maximum per surface
- 2.3.3 Method of honing: Use of a Supfina or equivalent raceway superfinishing machine

2.3.4 Depth of grinding

- a. Total depth of material removal from a raceway surface shall not exceed 0.003 in. (75 μm). The total combined (limiting) depth of material removal from both raceways of a single bearing shall not exceed 0.004 in. (100 μm). The limiting depth of removal shall be predicated on the increase in ball or roller size required to maintain original bearing internal clearances and that necessary to maintain minimum retainer (cage)/ball or roller pocket clearances as specified in the original OEM drawings and/or specifications. The replacement balls or rollers shall not be 0.004 in. (100 μm) greater in diameter and (for rollers) length than the standard OEM reference size.
- b. The inner and outer raceways and guide flanges may be ground to equal depths as required.
- c. Surface requirements: The raceway and guide flange surface finishes shall meet all OEM manufacturing/control drawings. If an OEM drawing is not available, an engineering standard specification shall be developed by source/vendor for bearing rework based on reverse-engineering data and approved by the original contractor or the cognizant government agency.

2.3.5 Machine feed rate and speed and material degradation prevention considerations: Machine feed rates and speeds shall be those used within the bearing industry and not be of a magnitude to cause grinding burns, furrows and/or overheating and/or softening of the ring surfaces.

2.3.6 Profile requirements: The raceway profile shall meet all OEM manufacturing/control drawings. If an OEM drawing is not available, an engineering standard specification shall be developed by source/vendor for bearing rework based on reverse-engineered data using a new OEM bearing or a good used but not a reworked bearing and must be approved by the original contractor or the cognizant government agency.

IMPORTANT: Since both honing/superfinishing and grinding rework processes are removing only a minute layer of material (0.0005 in. (12.5 μm) maximum for honing and 0.003 in. (75 μm) maximum for grinding per surface), there is no difference between the two methods with respect to procedural requirements. Usually the case depth ranges between 0.035 and 0.045 in. (890 and 1140 μm) in depth, and rework using restoration is allowed for one time only.

3. Refurbishing/Reusing Cages/Retainers

3.1 Dimensional Considerations

- 3.1.1 In general, an OEM bearing drawing does not contain detail design of the retainer (cage). The OEM relies on approved bearing suppliers to perform the detail design of the rolling elements, raceways, and retainers (cages). Supplier design approval by an OEM is based on the supplier's experience with bearing design, manufacture, service experience, and review and testing.
- 3.1.2 The approved vendor shall understand that the bearing retainer (cage) is a key element to the performance of the bearing and is a sensitive and critical rotating component. The reverse-engineering process shall address all the sensitive issues regarding dimensions, tolerances, material conditions, and cage instability.

3.2 Reverse-Engineering Procedure

3.2.1 Using OEM drawings

- 3.2.1.1 The vendor shall use all the dimensions and tolerances called out on the OEM drawings, if available. These dimensions are the critical dimensions designed by the OEM to control general bearing performance, and they include but are not limited to the following:

- a. Roller-to-retainer (cage) pocket clearance, axial and circumferential
- b. Retainer (cage) material (AMS specification) and baking conditions
- c. Retainer (cage) plating, specification, thickness, corner buildup
- d. Retainer (cage) width
- e. Retainer (cage) face-to-bearing face clearance
- f. Retainer (cage) face parallelism
- g. Retainer (cage) O.D.-to-cage I.D. concentricity
- h. Roller drop, minimum and maximum (cage-centered)
- i. Roller pocket location in cage diameter of true position
- j. Land riding shoulder diameter
- k. Cage unbalance limit
- l. Roller-to-cage retaining tang clearance (cage against outer shoulder)
- m. Cage hardness
- n. Cage O.D. and concentricity; I.D. tangs location; pocket corners dimensions; pocket finish; O.D. surface finish; corner breaks
- o. Cage landing diameter and pocket surface finishes

3.3 Requirements for Reverse Engineering

3.3.1 Drawings shall be in accordance with DOD-STD-100 and MIL-STD-880 and shall contain the information listed in the following paragraphs. Where existing drawings are incomplete, they may be supplemented to include the following data: bearing usage(s), qualified sources, change numbers, bearing installation, operating data necessary for analysis of the bearing as applied, and so forth. Separate sections may be utilized to define design and include process data and details to be covered by quality control requirements (see app. B).

3.3.2 General bearing information requirements

- a. Type of bearing
- b. Bore
- c. Outside diameter (O.D.)
- d. Width
- e. Pitch diameter
- f. ABMA class
- g. Size and number of rolling elements per row
- h. Number of rows of rolling elements
- i. Description of details for special mounting or removal procedures, such as puller grooves, retention, and so forth
- j. Radial clearance (total) and gage load for determining radial clearance
- k. Diametral clearance for retainer to pilot ring land
- l. Retainer (cage) overall width (max.)
- m. Retainer (cage) bore-to-O.D. concentricity
- n. Retainer land width
- o. Pilot ring locating diameter concentricity to pilot land
- p. Rolling-element-to-retainer-pocket clearance
- q. Ball or roller drop (max.)
- r. Minimum clearance between rolling element and retainer (cage) to be measured with rolling element and cage positioned in a simulated operating position to produce the closest approach between rolling-element and retainer (cage) retention feature
- s. Retainer material condition and hardness
- t. Retainer plating required and thickness per AMS 2412 or AMS 2410

- u. Surface finish roughness (AA) for rolling contact surfaces
- v. Surface roughness (AA) for mounting surface
- w. Surface finish roughness (AA) for retainer pockets and retainer piloting surfaces
- x. Lobing, waviness, and chatter tolerances applicable to bearing bore and outer diameter
- y. Surface treatments or coatings required
- z. Assembly cross-corner dimensions as required
- aa. Flushness requirements (where applicable)
- bb. End play or end float limits (max.) and gage load for each play check
- cc. Material for rings and rolling elements

AMS 6491 VIM-VAR AISI M-50
 AMS 6444 CEVM AISI 52100
 AMS 6276 CEVM AISI 8620 (carburized)
 AMS 6265 VIM-VAR AISI 9310 (carburized)
 AMS 5749 VIM-VAR BG-42
 AMS 6278 VIM-VAR M50 NiL (carburized)

- dd. Special heat treatment required to include details of microstructure and retained austenite requirements
- ee. Surface hardness RC (Rockwell “C” scale), as required, at operating temperatures:

Material	Minimum surface hardness, R_C
AMS 6491	60
AMS 6444	58
AMS 5749	60
AMS 6278	60

- ff. Bearing operating temperature range and stabilization temperature required to ensure against excessive growth of elements or undesirable transformation products, including retained austenite:

Material	Maximum retained austenite, percent
AMS 6491	3
AMS 6444	3
AMS 5749	5
AMS 6276	5
AMS 6265	5
AMS 6278	5

- gg. Required verification of bearing material procurement, inspection, and evaluation requirements to ensure cleanliness, grain control, and sufficiency of working after the ingot is formed to provide the documentation for traceability
- hh. Identification requirements
- ii. Requirements for nital etch staining to be removed from specific surfaces, where applicable
- jj. Inner-ring high point to be identified, if required
- kk. Grain orientation angle limit for rings

3.3.3 Cylindrical roller bearing requirements: In addition to the general requirements listed in section 3.3.2, the following are required for cylindrical roller bearings, where specified:

- a. Roller roundness
- b. Roller diameter and length, nominal
- c. Roller crown radius-to-crown drop coordinates
- d. Roller flat length and centrality

- e. Roller end squareness
- f. Roller corner radius runout with respect to roller cylindrical section, if required
- g. Roller to flange, end clearance
- h. Flange height and layback angle
- i. Roller corner dimensions
- j. Roller end finish (AA)
- k. Retainer (cage) balance tolerance and balancing speed, if required
- l. Diameter and length variation within one roller set
- m. Requirement, if any, for roller complement to be retained in the retainer (cage) when removed from its associated ring

3.3.4 Ball bearing requirements: In addition to the general requirements listed in section 3.3.3, the following are required for ball bearings where specified:

- a. Contact angle, unmounted; gage load for measuring
- b. Inner-ring groove radius as a percentage of ball diameter
- c. Outer-ring groove radius as a percentage of ball diameter
- d. Runout of split-ring contact face with respect to the bore of the split ring, if required
- e. Ring groove diameter and tolerance, if required
- f. Maximum step at race split
- g. Ball grade and ball complement diameter variation
- h. Ring grain orientation to be substantially parallel to groove surfaces, if required (may be negotiated)
- i. Retainer (cage) balance limit and balancing speed range; diameter for locating during balancing, if required
- j. Identification required to ensure alignment and load sharing of matched sets of multirow bearings
- k. Bearing preload, if applicable

3.3.5 Cage reverse-engineering method: The vendor shall use a minimum of five (5) OEM new and/or used (in good condition) cages for detail dimensions. If applicable, the cages shall be stripped of the silver plating. All cage dimensional, geometry, and finish parameters are measured using calibrated measuring devices, such as digital calipers, micrometers, and linear and circular tracing equipment (e.g., Federal 3200 Formscan System, Federal 5000 Surfanalyzer, and Taylor Hobson Form Talysurf).

3.3.5.1 The measured values shall be tabulated. A mean value shall be calculated using the measured values. A tolerance shall be assigned to the calculated mean value. The tolerance limits should not exceed the minimum or maximum measured values.

3.3.5.2 All measurements shall be kept on record at vendor and part of the reverse-engineering package submitted for approval. The records shall be kept for a duration of not less than 7 years or for a time specified by the cognizant government agency and/or OEM, whichever time is longer.

3.3.5.3 Particular attention shall be given to the retention features of the cage. Minimum and maximum material condition calculations shall be performed in order to make sure that the tab thickness and tab length variation are maintained within the measured values. Thus, the maximum material deformation of the tabs during bearing assembly (roller-to-cage retaining tang clearance condition) is at least as good as the originally manufactured cage.

IMPORTANT: The tolerance limits are chosen in such a way as to not exceed the minimum and maximum measured values or existing proven manufacturing standards. As a result of this procedure, the tolerances are typically tighter than the OEM manufacturing tolerance.

3.4 Cage Material Properties: In addition to the material information taken from OEM drawings (as AMS specification and hardness) if available, the vendor shall send out, to a specialized metallurgical laboratory, one OEM cage for complete metallurgical analysis to include

3.4.1 Chemical composition with listing of the material constituents in percentages

3.4.2 Material microstructure with picture taken at $\times 100$ or higher

3.4.3 Microhardness measurements

3.4.4 Identification of plating substrate/substrates and plating thickness

3.4.5 Material identification of nonmetallic cages by a specialized laboratory

3.5 Manufacturing Control

3.5.1 Cages shall be manufactured by manufacturing companies that have been qualified by the vendor or a cognizant government agency.

3.5.2 Received cages shall be dimensionally and geometrically checked at vendor. Samples shall be sent out for metallurgical testing.

3.5.3 Nondestructive testing shall be performed by a qualified source and validated by the vendor or a cognizant government agency. Retaining tangs shall be present for fit-up preparation.

3.5.4 Manufactured cages shall be sent out for silver plating per OEM drawing requirements or reverse-engineering data.

3.5.5 Nonmetallic cages shall be 100 percent visually inspected.

3.5.6 If required, cages shall be balanced per OEM drawing requirements or reverse-engineering data.

3.6 Fit-up and Assembly

3.6.1 Newly manufactured cages shall be used as replacement cages for the OEM cages found worn beyond repair limits. Vendor fit-up procedures are based on OEM drawing requirements, if available, and on overhaul manuals. See section 1.6 for cage reverse-engineering specification limits.

3.6.2 Particular attention shall be given to the cage retaining features:

- a. Roller-to-cage retaining tang clearance
- b. Roller drop

4. Manufacturing Replacement Rings: Level IV

4.1 All requirements shall be met as specified in the OEM drawings and/or as determined by reverse engineering as specified herein above as applies to replacement of either inner or outer rings and rolling elements. When available, new replacement rings shall be procured from the OEM. Upon assembly, all internal clearances and internal and external dimensions and fit-up shall correspond to that of the original bearing.

- 4.2 Where replacement rings are not available from the OEM, an engineering standard specification shall be developed by sources/vendor for bearing rework *based on reverse-engineering data* and approved by the original contractor or the cognizant government agency. The engineering standard specification shall list all dimensions, geometry, finish, fit-up, material, metallurgical, vibration/noise (dynamic analysis), inspection environmental conditions, quality assurance provisions, and other critical parameters not listed in the ANSI/ABMA standards.
- 4.3 A heat-treatment procedure for manufactured replacement rings not procured from the original OEM shall be developed by sources/vendor and approved by the original contractor or the cognizant government agency. The heat-treatment procedure shall list the metallurgical parameters: hardness, decarburization, grain size, microstructure, and retained austenite.

V. Rework Bearing Life Determination

1. Unused (New) Bearing Life Calculation – For most applications, bearing life is calculated based upon an L_{10} life or the time at which 90 percent of a population of bearings will be expected to exceed without failure and before which 10 percent of the population will have failed and have been removed from service. For critical applications, most bearings will have been removed from service for various reasons on or before the L_{10} life. Experience has shown that generally not more than 3 percent of these bearings will manifest a rolling-element fatigue spall (ref. 1).
2. Rework Bearing Life Calculation – The life of reworked bearings can be determined based on the method and analysis contained in references 14 and 15.
 - 2.1 The following life factors may be used to determine the life of those bearings subjected to Level I rework whereby the calculated L_{10} life of an unused (new) bearing is multiplied by the appropriate life factor LF_1 from table 3:

TABLE 3.—BEARING LIFE FACTOR LF_1 FOR LEVEL I REWORK
AS FUNCTION OF BEARING REMOVAL TIME FROM SERVICE

Time of removal	L_1	L_5	L_{10}	L_{15}	L_{20}	L_{30}	L_{40}	L_{50}
Life factor, LF_1	0.96	0.88	0.87	0.84	0.82	0.79	0.76	0.74

- 2.2 The following life factors may be used to determine the lives of those bearings subjected to Levels I through IV rework where the bearings were removed from service on or before their calculated L_{10} life. The appropriate life factor LF from table 4 is multiplied by the calculated L_{10} life of an unused (new) bearing to determine the life of the reworked (used) bearing.

TABLE 4.—REPRESENTATIVE LIFE FACTORS FOR REFURBISHED
AND RESTORED ROLLING-ELEMENT BEARINGS BASED ON LEVEL
OF REWORK AT BEARING L_{10} LIFE

Bearing type	Life factor, LF			
	Rework level			
	I	II	III	IV
Deep-groove ball	0.87	^a 0.88 to ^b 0.89	0.90	0.99
Angular-contact ball	0.87	^a 0.95 to ^b 0.96	0.96	>0.99
Cylindrical roller	0.87	^a 0.88 to ^b 0.89	0.90	0.99

^aWithout honing.

^bWith honing.

Appendix A

Glossary²

AA surface finish or arithmetic average. A numerical value of surface finish obtained by measuring the vertical distance from the mean line of an irregular surface to the profile in the same manner as with rms, adding these measurements, and dividing by the number of measurements. Care must be taken in interpreting AA values as they are not always listed with units, but depending upon the source, AA measurements may be reported in English or metric units.

ABEC 1, ABEC 5, ABEC 7, ABEC 9. Annular Bearing Engineers Committee (now ABMA) designations indicating degrees of ball bearing precision.

ABMA. American Bearing Manufacturers Association (formerly AFBMA, Anti-Friction Bearing Manufacturers Association).

accuracy. The quality of nearness to the true value; the number of significant figures in a number.

active surfaces. The areas on the rings, rolling elements, and cage that engage another surface in rolling or sliding contact, as the bearing rotates (e.g., ball-to-race path interface or cage land guide).

AFBMA. Anti-Friction Bearing Manufacturers Association (now ABMA).

angular-contact bearing. A type of ball bearing whose internal clearance and ball raceway locations are such so as to result in a definite contact angle and predetermined relationship of inner to outer ring surfaces when loaded axially.

ANSI. American National Standards Institute.

antifriction bearing. A bearing using rolling elements such as balls, rollers, or needle rollers.

AQL. Acceptable quality level; a value specified for a type or group of defects characteristic of an item or product. The specified AQL value (e.g., AQL of 0.4) is referred to in the appropriate sampling plan table of MIL-STD-105. The number of defects for each AQL is then obtained that will determine whether to accept or reject the lot.

austenite. A solid solution of ferric carbide or carbon in iron; cools to form pearlite or martensite.

axial clearance. See end play.

axial load (thrust). Force applied to the bearing in line with the bearing axis.

ball complement. Size and number of balls used in a ball bearing.

bearing axis. The imaginary centerline about which the outer or inner ring will revolve.

bearing stack. Matched multiple assembly of two or more bearings.

bore diameter. Inside diameter of inner ring.

²From ref. 11.

bore, outer ring. Inner diameter of outer ring.

boundary dimensions. Dimensions for bore, outside diameter, width, and corner(s).

burnish. A luster or polish on a surface caused by friction or rubbing contact.

cage (retainer, separator). A device partially surrounding the rolling elements and traveling with them, with the purpose of spacing or positioning the rolling elements in proper relationship to each other, preventing mutual rubbing or abrading.

cage pocket. That portion of the cage that is shaped to receive the rolling element.

catalogue life. Usually the bearing L_{10} life without life factors (LF).

centrifugal. Moving or acting in a direction away from a center or axis of rotation.

CEVM (also VAR). Consumable-electrode-vacuum-melted steel.

clearance, axial. See end play.

clearance, radial. Radial internal clearance is the total diametrical movement of the unclamped ring when the other ring is clamped and the specified radial load is reversed.

cone. The inner ring of a tapered roller bearing.

contact angle. Angle between the plane perpendicular to the bearing axis and the line drawn between the centers of contact of balls to the inner and outer ring raceways.

convex. A surface that is curved outward in the center.

corrosion. A process that destroys the metal by chemical or electrochemical action and converts it to an oxide, hydroxide, or sulfate compound.

crack. A break, fracture, fissure, crevice, or separation in the structure of a part.

critical defect. A defect that judgment and experience indicate is likely to result in hazardous or unsafe conditions for persons using, maintaining, or depending upon the product; or a defect that judgment and experience indicate is likely to prevent performance of the tactical function of a major end item, such as an aircraft, missile, or space vehicle.

crowned roller. Having a very large radius profile on both sides of a straight cylindrical center section to provide a modified line contact with the raceways.

defect (discrepancy). Any deviation of a part from specified requirements.

diametrical stability. The degree of stability that hardened steel may have to resist growth or permanent expansion (a function of the amount of retained austenite).

duplex bearing. Single-row ball or tapered roller bearings specially ground for use in matched sets. They are manufactured with a controlled relationship of axial location of the inner and outer ring faces. Usually they are arranged in pairs for mounting face-to-face (DF), back-to-back (DB), or in tandem (DT). When a set comprises more than two bearings, they are arranged in tandem or in combinations of DT–DB or DT–DF.

dynamic balance. That condition in a rotating body reflecting how closely the mass axes are coincident or the same as the rotational axis.

eccentricity (radial runout). Occurs when the center of one circular surface is not coincident (the same as) with the center of another surface (e.g., nonuniform thickness between the bore and the ball groove of an inner ring).

end play (test). The bearing is to be lubricated with light oil and one of its rings clamped to prevent axial movement. The specified reversing measuring load is applied to the unclamped ring so that the resultant movement of that ring is parallel to the bearing axis. The end play is the total movement of the unclamped ring when the load is applied first in one direction and then in the other.

flaking. A condition of advanced surface fatigue where small pieces of metal are loosened from the base material.

fluting. A form of pitting in which pits occur in a regular pattern so as to form transverse grooves or flutes in the raceway.

fretting (fret wear, fretting corrosion, false Brinelling). The rapid abrasion that occurs at the interface between contacting, highly loaded metal surfaces when subjected to vibratory motions of low amplitude, usually accompanied by the formation of oxides of the abraded metal.

galling. The transfer of material from one surface to another during sliding contact.

groove runout with reference side, inner ring. See raceway runout with reference side, inner ring.

groove runout with reference side, outer ring. See raceway runout with reference side, outer ring.

hardness. Resistance of metal to plastic deformation, determined by indentation.

height of raceway shoulder. Distance from bottom of respective raceway to inner-ring outer diameter or outer-ring inner diameter (same as race depth).

inclusion. A void, discontinuity, or solid foreign particle in the molecular structure of a metal.

inner race. Raceway of inner ring.

inner ring. The inner component of a bearing.

inside diameter. Dimension across center of ring bore; may be used to express dimension across bore of snap ring, shield, seal, etc.

inspection. The process of measuring, examining, testing, or otherwise comparing the unit or product (bearing) with the requirement.

inspection, quality conformance (CQI). All examinations and tests performed for the purpose of determining conformance with specified requirements.

inspection, 100 percent. An inspection in which specified characteristics of each bearing are examined or tested to determine conformance with requirements.

internal clearance. See clearance, radial.

L_5 life. Bearing 5-percent life or operating time exceeded by 95 percent of a group of identical bearings will attain or exceed before the first indication of fatigue cracking or spalling.

L_{10} life. Bearing 10-percent life or operating time exceeded by 90 percent of a group of identical bearings will attain or exceed before the first indication of fatigue cracking or spalling.

L_{15} life. Bearing 15-percent life or operating time exceeded by 85 percent of a group of identical bearings will attain or exceed before the first indication of fatigue cracking or spalling.

L_{20} life. Bearing 20-percent life or operating time exceeded by 80 percent of a group of identical bearings will attain or exceed before the first indication of fatigue cracking or spalling.

L_{30} life. Bearing 30-percent life or operating time exceeded by 70 percent of a group of identical bearings will attain or exceed before the first indication of fatigue cracking or spalling.

L_{40} life. Bearing 40-percent life or operating time exceeded by 60 percent of a group of identical bearings will attain or exceed before the first indication of fatigue cracking or spalling.

L_{50} life. Bearing 50-percent life or operating time exceeded by 50 percent of a group of identical bearings will attain or exceed before the first indication of fatigue cracking or spalling.

lands. The flat surfaces on either side of the raceway or rings.

land-riding retainer. A retainer guided by either the inner-ring or outer-ring lands.

laps. Discontinuities or irregularities in the material as a result of heading or forging.

lay. Direction of the predominant surface pattern.

life factor (LF). Life-modifying factor to adjust bearing life calculated from ABMA/ANSI/ISO standards or from the manufacturer's catalogue.

loading groove (filling slot). Notch in raceway to permit assembly of a maximum number of rolling elements.

loading groove bearing. A bearing of maximum capacity type in which there is introduced, by means of a filling slot or loading groove, more balls or rollers than can be incorporated in a nonfilling slot or Conrad-type bearing.

lot. This term shall mean inspection lot, a collection of bearings or kits from which a sample is to be drawn and inspected to determine conformance with the acceptability criteria.

lot size. The number of bearings in a lot.

major defect. A defect, other than critical, that is likely to result in failure or to materially reduce the usability of the product for its intended purpose.

martensite. A phase of steel with a body-centered crystalline structure characterized by a needlelike microstructure.

matching. Inner and outer rings in duplex bearing sets that are matched for face flushness, bore, O.D., and eccentricity, within specified tolerances.

micrometer. One millionth of a meter; 1 micron equals 0.00003937 in.

minor defect. A defect that is not likely to materially reduce the usability of the bearing for its intended purpose or is a departure from established standards having minimal influence on the effective use of the operation of the unit.

nominal. Approximate or rated value.

outside diameter squareness with side (test). One side of the outer ring is supported on a flat plate of suitable dimensions (with inner ring free) and held against a stop located close to the lower corner of the outside diameter. The indicator is applied directly above the stop close to the upper corner of the outside diameter. The deviation from the outside diameter squareness with the side is the difference between the minimum and maximum reading of the indicator when rotating the outer ring one revolution.

parallelism of sides. The difference between the largest and smallest width of the bearing rings.

pitch diameter, rolling elements. The diameter of the centerline of the rolling elements.

pitting. Minute removal of material from surfaces through fatigue, corrosion, or electrical arcing.

plastic flow. Deformation that permanently remains after removing the load that caused it.

pocket cage. See cage pocket.

precision. The degree of agreement of repeated measurements of a quantity. Compare with accuracy.

preload. Predetermined internal thrust (axial) load deliberately imposed by design in certain duplex bearing sets to provide increased radial and/or axial rigidity.

processed bearing. A bearing that has been used and then cleaned, inspected, gauged, tested, and preserved for additional use.

profile. The contour (external outline) of a surface in a plane perpendicular (right angle) to the surface.

profile (measured). A representation of the profile obtained by instrumental means.

QCL. Quality characteristics list.

race. Same as raceway.

raceway. The contact path of the rolling element on rings of roller bearings.

raceway diameter. Diameter of the inner- or outer-ring raceway of a bearing.

raceway, inner ring. Roller or ball track or groove in the inner ring.

raceway, outer ring. Roller or ball track or groove in the outer ring.

raceway runout, with reference side, inner ring (test). Mount bearing on arbor having a very slight taper (preferably 0.0001 to 0.0002 in. on the diameter per inch of length or 0.1 to 0.2 μm per millimeter of length). Support outer ring in horizontal position and apply indicator to side of inner ring. The deviation from groove parallelism with side is the difference between the maximum and the minimum readings when rotating the arbor one revolution.

raceway runout, with reference side, outer ring (test). Mount bearing on arbor having a very slight taper (preferably 0.0001 to 0.0002 in. on the diameter per inch of length or 0.1 to 0.2 μm per millimeter of length). Apply a true running weight to the outer ring. Support arbor in a vertical position and apply indicator to side of outer ring. The deviation from groove parallelism with side is the difference between the maximum and minimum readings when rotating outer ring one revolution.

radial clearance. See clearance, radial.

radial load. Force applied to the inner or outer rings perpendicular to the bearing axis.

radial runout (test). Mount bearing on arbor having a very slight taper (0.0001 to 0.0002 in. on the diameter per inch of length or 0.1 to 0.2 μm per millimeter of length). Apply indicator on center of stationary outer ring. The radial runout is the difference between the maximum and minimum readings when rotating the arbor one revolution. Corrections should be made for the inaccuracy of the arbor.

radial-type bearing. A rolling-element bearing primarily designed to support a radial load perpendicular to the shaft axis

random sampling. A plan for choosing sample units in a random or nonregular pattern for quality inspection.

rating life (same as L_{10} life). Number of hours without life factors (LF) at a given load and speed that 90 percent of a group of identical bearings will attain or exceed before the first indication of fatigue cracking or spalling.

RBEC 1, RBEC 5. Designations indicating degrees of roller bearing precision; Roller Bearing Engineers Committee (AFBMA now ABMA).

refinish. To restore an existing surface finish without removing all the existing finish.

refurbishment. The process of removing the rolling elements from used bearings, disassembling, inspecting, and cleaning the bearing, and replacing the rolling elements with new elements.

restoration. The process of grinding the raceways of used bearings and replacing the rolling elements with oversized elements whereby the internal geometry and clearances in the bearing are maintained.

retained austenite. Volume fraction of austenite remaining untransformed at ambient temperature in high-carbon steel after heat treatment that can transform into bainite or martensite with time, temperature, and/or stress to form residual stresses or cause ring growth.

retainer. See cage.

rework. The overall procedure for cleaning, reworking, refurbishing, restoring, and reissuing used or rejected bearings.

Rockwell hardness test. A test for determining the hardness of a material based on the depth of penetration of a specified penetrator into the specimen under specified load conditions.

roller. Load-carrying rolling element of cylindrical, conical, or curvilinear contour.

roller complement. Size and number of rollers in a bearing.

roller diameter. Maximum diameter of straight rollers.

roller length. Distance between the ends or faces of the roller.

rolling bearing or rolling-element bearing. A bearing using rolling elements, such as balls, rollers, or needles, to reduce friction and to support load.

root mean square (surface finish; rms). Numerical value of surface finish obtained by measuring from the mean line of an irregular surface to the profile and squaring each height value in the data set, then taking the square root of the mean, usually reported in micrometers (μm) or microinches ($\mu\text{in.}$).

running track. Same as raceway.

runout. The amount that one surface lacks of being coplanar with another surface of the same part.

runout, radial. See radial runout.

sample. A sample consists of one or more parts drawn from a lot, the parts being selected at random without regard to their quality.

sampling plan. The number of bearings from each lot that are to be inspected and the criteria for determining the acceptability of the lot.

scratches. Linear abrasions on a surface.

scuffs. A series of small superficial or shallow scratches.

separable. A bearing assembly that may be completely or partially disassembled without permanently deforming any of its component parts.

separator. See cage.

side runout, inner rig (test). Mount bearing on arbor having a very slight taper (0.0001 to 0.0002 in. on the diameter per inch of length or 0.1 to 0.2 μm per millimeter of length). Apply indicator against side of inner ring. The side runout is the difference between the maximum and minimum readings when rotating the arbor one revolution.

skew. Slant, twist; nonsymmetrical, nonuniform distribution.

smearing or pickup. Removal of raceway, ball, or cage material due to skidding contact and its deposition at another point in the form of a smear.

spalling. Actual removal of material from raceway or rolling-element surfaces in the form of flakes, resulting in cavities (fatigue related); generally limited in depth to the zone of the maximum shearing stresses and to the width of the running track.

squareness of O.D./bore with face. The squareness (90° angle) of the face with the outside diameter/bore of a ring.

staking. A method of retaining a bearing by displacing housing material over the chamfer or displacing retainer material to contain a rolling element in the pocket.

stains. Surface discoloration.

standard. A physical or numerical limit that is used as a reference.

statistical. Of, relating to, or dealing with the collection and analytical interpretation of numerical data.

superficial. Affecting only the surface of an object.

surface texture. The pattern of the surface formed by repetitive or random deviations from the nominal surface. Includes roughness, waviness, lay, and flaws.

tandem duplex mounting. Assembly of two more ball bearings mounted so as to divide the thrust load.

tarnish. A stain on the surface.

temper. To soften hardened steel by reheating at a temperature below the hardening temperature.

thrust bearing. A ball or roller bearing with space between rings oriented perpendicular to the axis of rotation. It is primarily intended to carry thrust loads.

used bearing. A bearing that has seen service and has been subjected to operating loads.

VAR. Vacuum-arc-remelted steel (same as CEVM).

VIM. Vacuum-induction-melted steel.

VIM–VAR. Vacuum-induction-melted, vacuum-arc-remelted steel (also double vacuum melted).

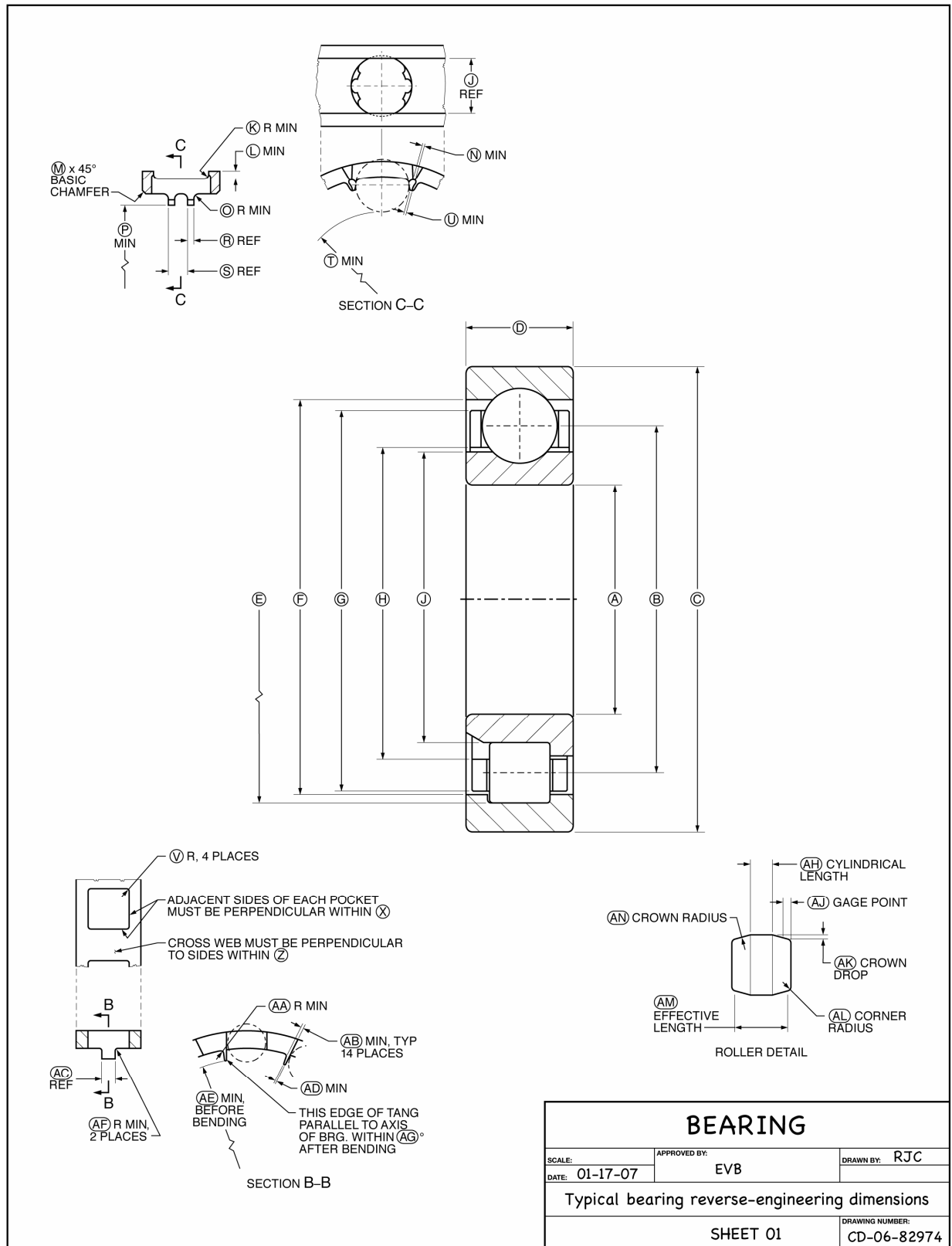
width, bearing. The width of the individual ring and cage parts or the face of the inner ring to the opposite face of the maximum axial envelope dimension, whichever is greater.

width, inner ring. Dimension across the inner ring.

width, outer ring. Dimension across the outer ring.

APPENDIX B

Typical Drawings With Data Formats



Worksheet for Reverse-Engineering Dimensions
(To be used in conjunction with Sheet 01, CD-06-82974)

Designation	Dimension	Designation	Dimension
A		V	
B		X	
C		Z	
D		AA	
E		AB	
F		AC	
G		AD	
H		AE	
I		AF	
J		AG	
K		AH	
L		AJ	
M		AK	
N		AL	
O		AM	
P		AN	
R			
S			
T			
U			

General Bearing Data

1	This bearing must conform to the premium aircraft quality requirements of material spec, unless otherwise specified:		
2	ABMA class (ABEC or RBEC)		
3	Size of rolling elements		
4	Number of rows of rolling elements		
5	Number of rolling elements per row		
6	Radial clearance under gage load at room temperature		
7	Rolling element and ring material	Hardness, R _c	
		Specification	
8	Surface roughness (µin. AA)	Ring pilot surface	
		Retainer pocket	
		Retainer pilot surface	
		Bearing O.D.	
		Bearing bore	
		Inner race	
		Outer race	
		Rolling element (O.D. for roller)	
9	Bearing materials stabilized to operate at (operating temperature range)		
10	Cross corner dimension with end play removed		
11	Pitch diameter		
12	Pilot ring locating diam. concentricity		
13	Vendor identification requirements		
14	Vendor substantiation required		
15	Nital etch stains to be removed		
16	Inner ring high point of eccentricity to be identified		
17	Special heat treat required to include details of microstructure and retained austenite requirements		
			per spec:

Ball Bearing Data

1	Race groove curvature % of ball diameter	Outer	
		Inner	
2	Race groove depth % of ball diameter	Outer	
		Inner	
3	Rest angle for split rings		
4	Max. step at split (split rings)		
5	Shim thickness for split rings		
6	Contact angle under gage load		
7	End play under gage load		
8	Runout of split ring contact face with respect to bore of split ring		
9	Ring grain orientation to be substantially parallel to groove surfaces per spec:		
10	Runout of inner ring O.D. when bore is used as ref.		
11	Ball grade		
12	Ball lot diam. variation in a single row shall not exceed		
13	Cage unbalance, max.		
14	Ball pocket location of true position, axially/circumferentially		
15	Ball to retainer (cage) pocket clearance		

Note:

Hardness of balls shall be equal to but no less than the hardness of the rings, and no greater than two points, Rockwell “C” hardness of the rings.

Roller Bearing Data

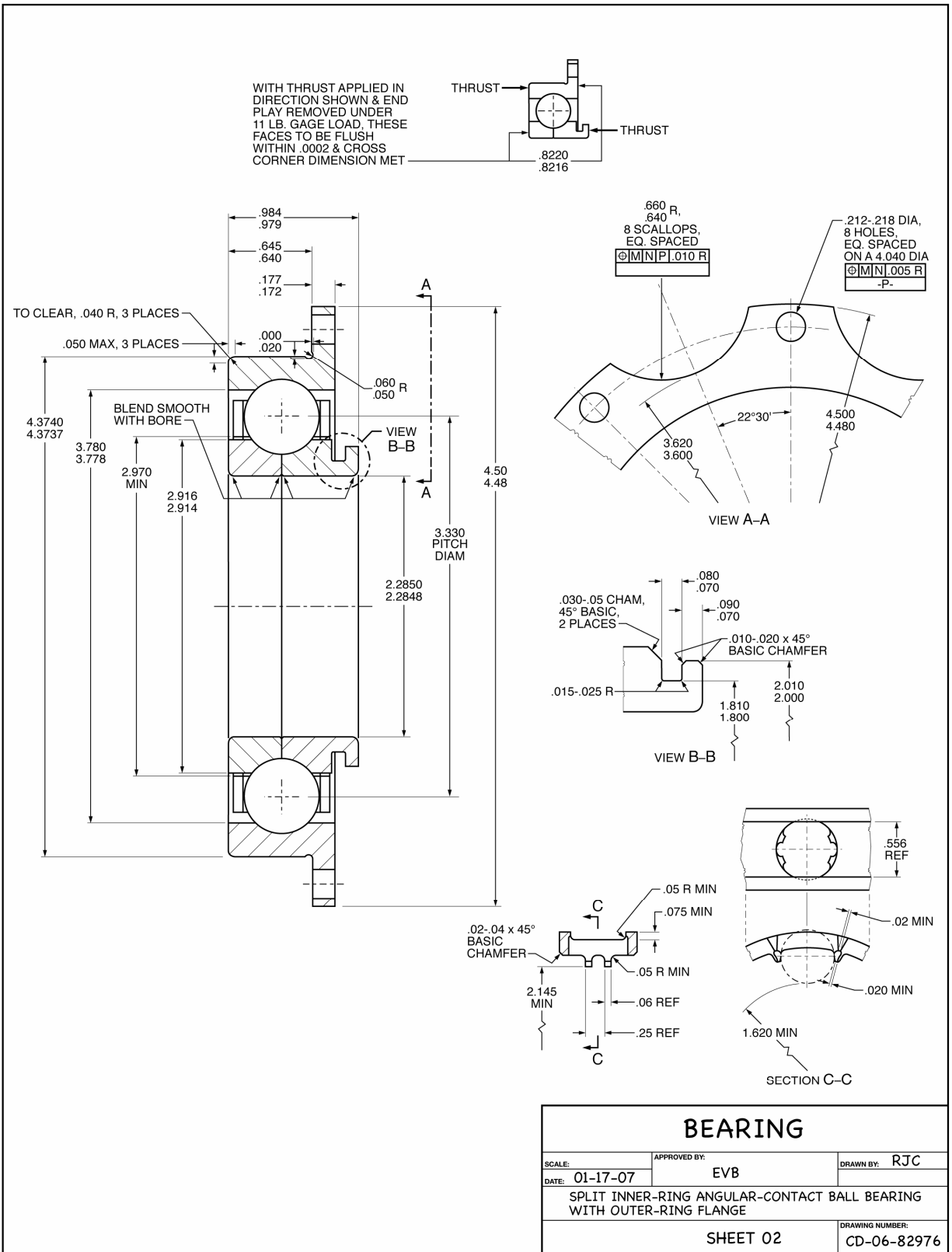
1	Roller flat length cylindricity or roundness		
2	Roller crown radius		
3	Roller crown drop at gage point		
4	Roller flat length		
5	Roller flat centrality		
6	Roller end squareness/parallelism		
7	Roller corner radius runout with respect to roller cylindrical section		
8	Roller to flange end clearance (roller end clearance)		
9	Flange height		
10	Flange layback angle		
11	Roller corner radius		
12	Roller end face finish		
13	Retainer (cage) unbalance, max.		
14	Roller length and diameter variation per bearing		
15	Roller drop (roller centered in retainer)		
16	Minimum clearance-roller to retainer retention		
17	Roller pocket location of true position, axially/circumferentially		
18	Roller to retainer (cage) pocket clearance, axial/circumferential		

Note:

Hardness of rollers shall be equal to but no less than the hardness of the rings, and no greater than two points, Rockwell “C” hardness of the rings.

Retainer (Cage) Data

1	Retainer (dimensions and engineering requirements are after plating)		
2	Retainer (cage) type		
3	Retainer (cage) pilot clearance, diametral		
4	Retainer (cage) radial height (min.)		
5	Retainer (cage) width		
6	Retainer (cage) weight, lb		
7	Retainer (cage) land riding diameter		
8	Retainer (cage) material specification		
9	Retainer (cage) hardness, R _c		
10	Retainer (cage) plating specification		
11	Retainer (cage) plating thickness		
12	Retainer (cage) type of retention		
13	Retainer (cage) bore to O.D. concentricity		
14	Retainer (cage) land width (min. effective)		
15	Retainer (cage) face to bearing face clearance		



General Bearing Data

1	This bearing must conform to the premium aircraft quality requirements of material spec, unless otherwise specified: AMS 6491		
2	ABMA class (ABEC or RBEC)		5
3	Size of rolling elements		0.5625
4	Number of rows of rolling elements		1
5	Number of rolling elements per row		12
6	Radial clearance under gage load at room temperature		0.0039 to 0.0047
7	Rolling element and ring material	Hardness, R _c	60 to 64
		Specification	B50TF – 10366M
8	Surface roughness (μin. AA)	Ring pilot surface	12
		Retainer pocket	32
		Retainer pilot surface	32
		Bearing O.D.	16
		Bearing bore	16
		Inner race	4
		Outer race	4
		Rolling element (O.D. for roller)	2
9	Bearing materials stabilized to operate at (operating temperature range)		–65 to +800 °F
10	Cross corner dimension with end play removed		0.6698 to 0.6752
11	Pitch diameter		2.484
12	Pilot ring locating diam. concentricity		0.001
13	Vendor identification requirements		Per customer request
14	Vendor substantiation required		Yes
15	Nital etch stains to be removed		Yes
16	Inner ring high point of eccentricity to be identified		Yes
17	Special heat treat required to include details of microstructure and retained austenite requirements		per spec: AMS 2759/2

Ball Bearing Data

1	Race groove curvature % of ball diameter	Outer	51.75 to 52.25
		Inner	51.75 to 52.25
2	Race groove depth % of ball diameter	Outer	20
		Inner	25
3	Rest angle for split rings		10.24°
4	Max. step at split (split rings)		0.0001
5	Shim thickness for split rings		0.004
6	Contact angle under gage load		24° to 28°
7	End play under gage load		0.018
8	Runout of split ring contact face with respect to bore of split ring		0.0001
9	Ring grain orientation to be substantially parallel to groove surfaces per spec:		-----
10	Runout of inner ring O.D. when bore is used as ref.		0.0004
11	Ball grade		10
12	Ball lot diam. variation in a single row shall not exceed		20 μin.
13	Cage unbalance, maximum		3 gm-cm
14	Ball pocket location of true position, axially/circumferentially		0.006 0.006
15	Ball to retainer (cage) pocket clearance		0.012 to 0.015

Note:

Hardness of balls shall be equal to but no less than the hardness of the rings, and no greater than two points, Rockwell “C” hardness of the rings.

Roller Bearing Data

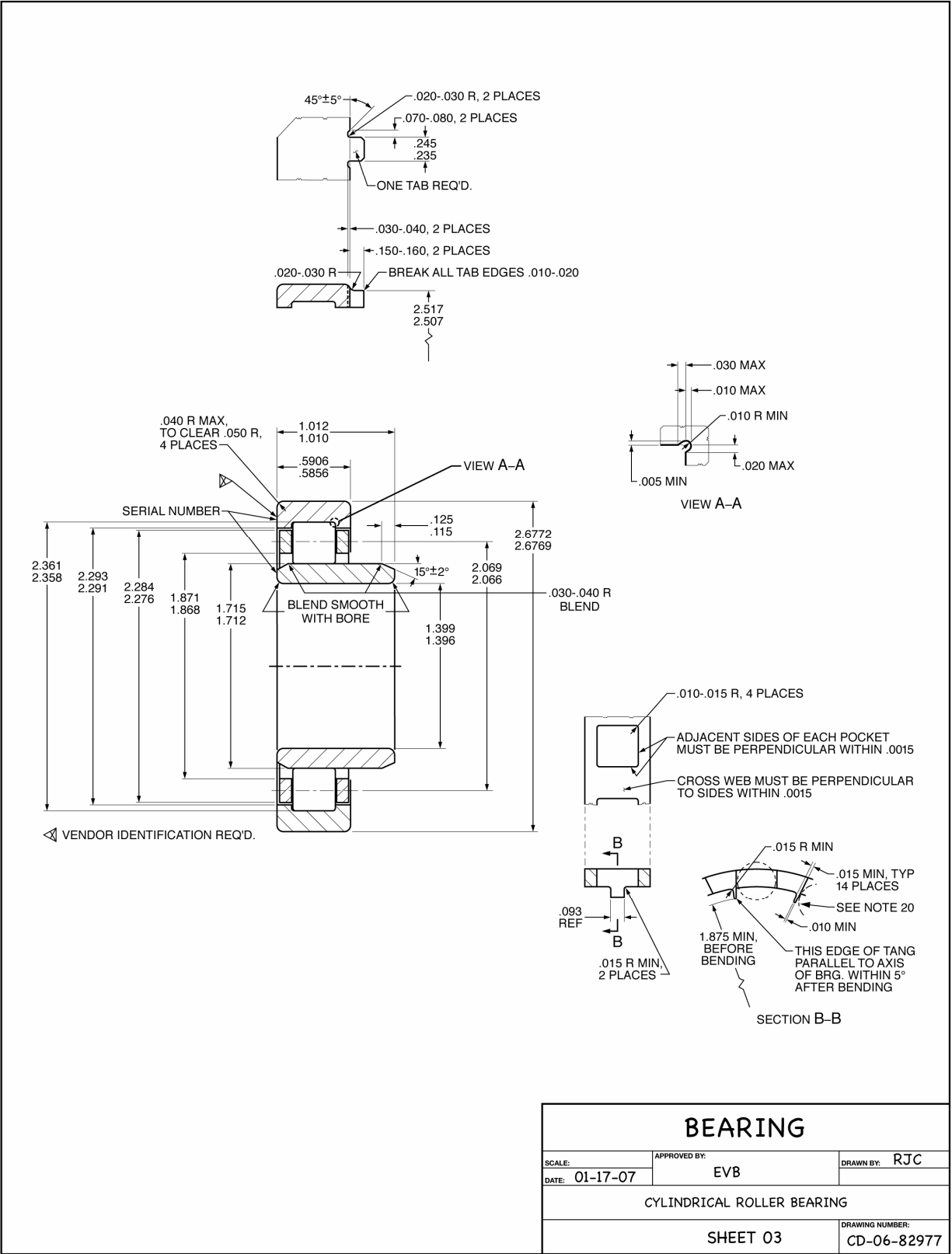
1	Roller flat length cylindricity or roundness	N/A	
2	Roller crown radius	N/A	
3	Roller crown drop at gage point	N/A	
4	Roller flat length	N/A	
5	Roller flat centrality	N/A	
6	Roller end squareness/parallelism	N/A	
7	Roller corner radius runout with respect to roller cylindrical section	N/A	
8	Roller to flange end clearance (roller end clearance)	N/A	
9	Flange height	N/A	
10	Flange layback angle	N/A	
11	Roller corner radius	N/A	
12	Roller end face finish	N/A	
13	Retainer (cage) unbalance, max.	N/A	
14	Roller length and diameter variation per bearing	N/A	
15	Roller drop (roller centered in retainer)	N/A	
16	Min. clearance-roller to retainer retention	N/A	
17	Roller pocket location of true position, axially/circumferentially	N/A	N/A
18	Roller to retainer (cage) pocket clearance, axial/circumferential	N/A	N/A

Note:

Hardness of rollers shall be equal to but no less than the hardness of the rings, and no greater than two points, Rockwell “C” hardness of the rings.

Retainer (Cage) Data

1	Retainer (dimensions and engineering requirements are after plating)	
2	Retainer (cage) type	One piece, inner-land guided
3	Retainer (cage) pilot clearance, diametral	0.012 to 0.017
4	Retainer (cage) radial height (minimum)	0.360
5	Retainer (cage) width	0.703 to 0.771
6	Retainer (cage) weight, lb	-----
7	Retainer (cage) land riding diameter	2.368 min
8	Retainer (cage) material specification	AMS 6414
9	Retainer (cage) hardness, R _c	30 to 35
10	Retainer (cage) plating specification	AMS 2412
11	Retainer (cage) plating thickness	0.001 to 0.002
12	Retainer (cage) type of retention	Internal tang
13	Retainer (cage) bore to O.D. concentricity	0.005
14	Retainer (cage) land width (minimum effective)	0.103
15	Retainer (cage) face to bearing face clearance	0.005



General Bearing Data

1	This bearing must conform to the premium aircraft quality requirements of material spec, unless otherwise specified: AMS 6491		
2	ABMA class (ABEC or RBEC)		5
3	Size of rolling elements		0.2756×0.2756
4	Number of rows of rolling elements		14
5	Number of rolling elements per row		1
6	Radial clearance under gage load at room temperature		0.0010 to 0.0014
7	Rolling element and ring material	Hardness, R _c	60 to 64
		Specification	B50TF – 103CL-A
8	Surface roughness (μin. AA)	Ring pilot surface	12
		Retainer pocket	32
		Retainer pilot surface	32
		Bearing O.D.	16
		Bearing bore	16
		Inner race	4
		Outer race	4
		Rolling element (O.D. for roller)	4
9	Bearing materials stabilized to operate at (operating temperature range)		–65 to +800 °F
10	Cross corner dimension with end play removed		N/A
11	Pitch diameter		2.1260
12	Pilot ring locating diam. concentricity		0.0005
13	Vendor identification requirements		Per customer request
14	Vendor substantiation required		Yes
15	Nital etch stains to be removed		Yes
16	Inner ring high point of eccentricity to be identified		Yes
17	Special heat treat required to include details of microstructure and retained austenite requirements		per spec: AMS 2759/2

Ball Bearing Data

1	Race groove curvature % of ball diameter	Outer	N/A
		Inner	N/A
2	Race groove depth % of ball diameter	Outer	N/A
		Inner	N/A
3	Rest angle for split rings		N/A
4	Max. step at split (split rings)		N/A
5	Shim thickness for split rings		N/A
6	Contact angle under gage load		N/A
7	End play under gage load		N/A
8	Runout of split ring contact face with respect to bore of split ring		N/A
9	Ring grain orientation to be substantially parallel to groove surfaces per spec:		N/A
10	Runout of inner ring O.D. when bore is used as ref.		N/A
11	Ball grade		N/A
12	Ball lot diam. variation in a single row shall not exceed		N/A
13	Cage unbalance, max.		N/A
14	Ball pocket location of true position, axially/circumferentially	N/A	N/A
15	Ball to retainer (cage) pocket clearance		N/A

Note:

Hardness of balls shall be equal to but no less than the hardness of the rings, and no greater than two points, Rockwell “C” hardness of the rings.

Roller Bearing Data

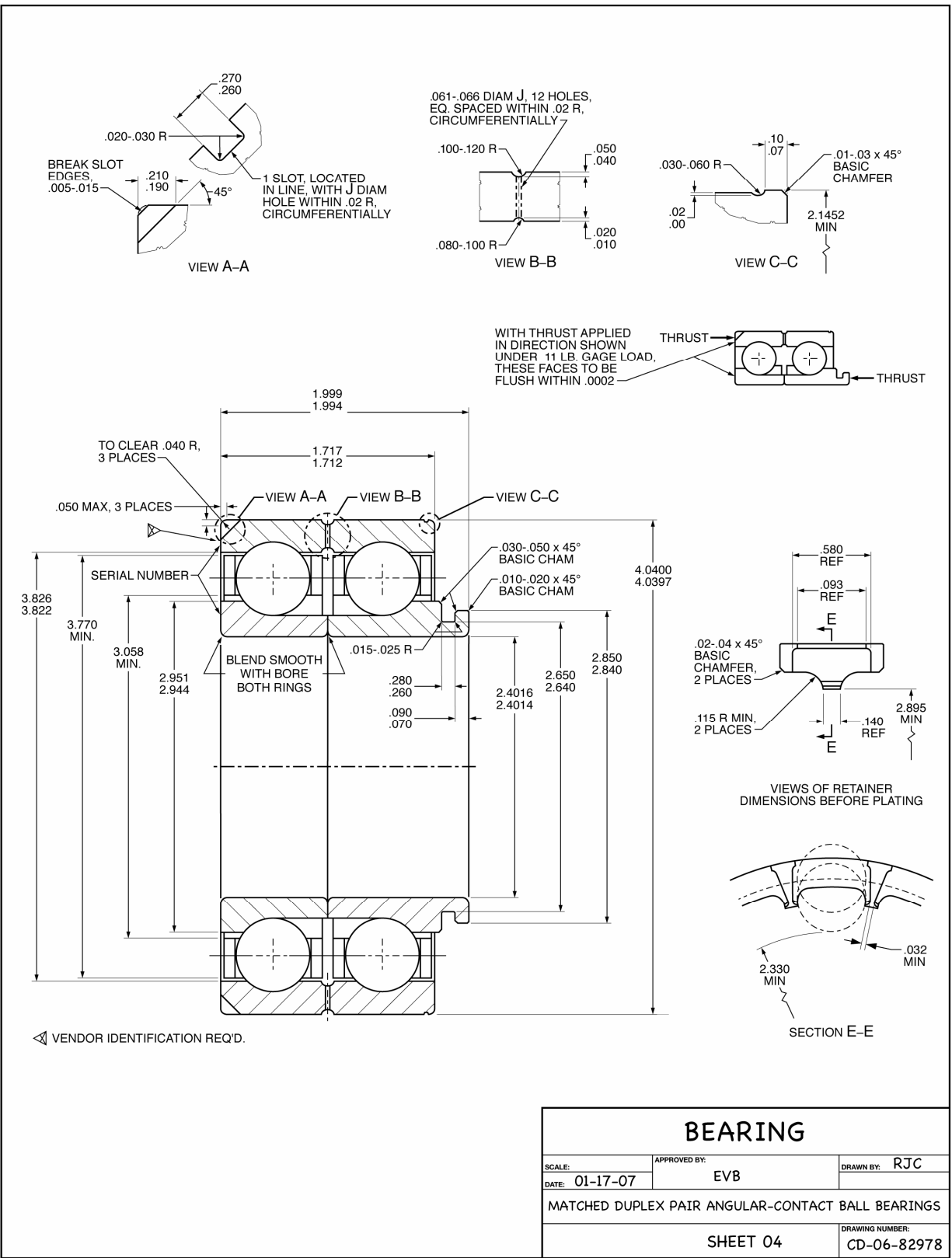
1	Roller flat length cylindricity or roundness	0.120 to 0.170	
2	Roller crown radius	25 in.	
3	Roller crown drop at gage point	0.00005 to 0.2456	
4	Roller flat length	0.2356 to 0.2456	
5	Roller flat centrality	0.1010	
6	Roller end squareness/parallelism	0.001	
7	Roller corner radius runout with respect to roller cylindrical section	0.0005	
8	Roller to flange end clearance (roller end clearance)	0.0006 to 0.0018	
9	Flange height	0.0556	
10	Flange layback angle	0°00' to 0°30'	
11	Roller corner radius	0.015 to 0.030	
12	Roller end face finish	6	
13	Retainer (cage) unbalance, max.	3 gm-cm	
14	Roller length and diameter variation per bearing	0.040 max.	
15	Roller drop (roller centered in retainer)	0.015 to 0.040	
16	Min. clearance-roller to retainer retention	0.003	
17	Roller pocket location of true position, axially/circumferentially	0.006	0.006
18	Roller to retainer (cage) pocket clearance, axial/circumferential	0.006 to 0.013	0.005 to 0.013

Note:

Hardness of rollers shall be equal to but no less than the hardness of the rings, and no greater than two points, Rockwell “C” hardness of the rings.

Retainer (Cage) Data

1	Retainer (dimensions and engineering requirements are after plating)	
2	Retainer (cage) type	One piece, outer-land guided
3	Retainer (cage) pilot clearance, diametral	0.006 to 0.014
4	Retainer (cage) radial height (min.)	0.115
5	Retainer (cage) width	0.476
6	Retainer (cage) weight, lb	-----
7	Retainer (cage) land riding diameter	2.291 to 2.293
8	Retainer (cage) material specification	AMS 6414
9	Retainer (cage) hardness, R _c	28 to 32
10	Retainer (cage) plating specification	AMS 2412
11	Retainer (cage) plating thickness	0.001 to 0.002
12	Retainer (cage) type of retention	Bent tab
13	Retainer (cage) bore to O.D. concentricity	0.002
14	Retainer (cage) land width (min. effective)	0.087
15	Retainer (cage) face to bearing face clearance	0.030 min.



General Bearing Data

1	This bearing must conform to the premium aircraft quality requirements of material spec, unless otherwise specified: AMS 6491		
2	ABMA class (ABEC or RBEC)		7
3	Size of rolling elements		0.5625
4	Number of rows of rolling elements		1
5	Number of rolling elements per row		15
6	Radial clearance under gage load at room temperature		0.0038 to 0.0046
7	Rolling element and ring material	Hardness, R _c	60 to 64
		Specification	B50TF – 103CL–A
8	Surface roughness (μin. AA)	Ring pilot surface	12
		Retainer pocket	32
		Retainer pilot surface	32
		Bearing O.D.	16
		Bearing bore	16
		Inner race	4
		Outer race	4
		Rolling element (O.D. for roller)	2
9	Bearing materials stabilized to operate at (operating temperature range)		–65 to +800 °F
10	Cross corner dimension with end play removed		N/A
11	Pitch diameter		3.228
12	Pilot ring locating diam. concentricity		0.002
13	Vendor identification requirements		Per customer request
14	Vendor substantiation required		Yes
15	Nital etch stains to be removed		Yes
16	Inner ring high point of eccentricity to be identified		Yes
17	Special heat treat required to include details of microstructure and retained austenite requirements		per spec: AMS 2759/2

Ball Bearing Data

1	Race groove curvature % of ball diameter	Outer	51.75 to 52.25
		Inner	51.75 to 52.25
2	Race groove depth % of ball diameter	Outer	20
		Inner	25
3	Rest angle for split rings		N/A
4	Max. step at split (split rings)		N/A
5	Shim thickness for split rings		N/A
6	Contact angle under gage load		22°30' to 27°30'
7	End play under gage load		0.0034 to 0.0037
8	Runout of split ring contact face with respect to bore of split ring		0.0001
9	Ring grain orientation to be substantially parallel to groove surfaces per spec:		-----
10	Runout of inner ring O.D. when bore is used as ref.		0.00025
11	Ball grade		10
12	Ball lot diam. variation in a single row shall not exceed		10 μin.
13	Cage unbalance, max.		3 gm-cm
14	Ball pocket location of true position, axially/circumferentially		0.006 0.006
15	Ball to retainer (cage) pocket clearance		0.015 to 0.021

Note:

Hardness of balls shall be equal to but no less than the hardness of the rings, and no greater than two points, Rockwell “C” hardness of the rings.

Roller Bearing Data

1	Roller flat length cylindricity or roundness	N/A
2	Roller crown radius	N/A
3	Roller crown drop at gage point	N/A
4	Roller flat length	N/A
5	Roller flat centrality	N/A
6	Roller end squareness/parallelism	N/A
7	Roller corner radius runout with respect to roller cylindrical section	N/A
8	Roller to flange end clearance (roller end clearance)	N/A
9	Flange height	N/A
10	Flange layback angle	N/A
11	Roller corner radius	N/A
12	Roller end face finish	N/A
13	Retainer (cage) unbalance, max.	N/A
14	Roller length and diameter variation per bearing	N/A
15	Roller drop (roller centered in retainer)	N/A
16	Min. clearance-roller to retainer retention	N/A
17	Roller pocket location of true position, axially/circumferentially	N/A
18	Roller to retainer (cage) pocket clearance, axial/circumferential	N/A

Note:

Hardness of rollers shall be equal to but no less than the hardness of the rings, and no greater than two points, Rockwell “C” hardness of the rings.

Retainer (Cage) Data

1	Retainer (dimensions and engineering requirements are after plating)	
2	Retainer (cage) type	One piece, outer-land guided
3	Retainer (cage) pilot clearance, diametral	0.012 to 0.017
4	Retainer (cage) radial height (min.)	0.356
5	Retainer (cage) width	0.763 to 0.771
6	Retainer (cage) weight, lb	-----
7	Retainer (cage) land riding diameter	3.822 to 3.826
8	Retainer (cage) material specification	AMS 6414
9	Retainer (cage) hardness, R _c	28 to 32
10	Retainer (cage) plating specification	AMS 2412
11	Retainer (cage) plating thickness	0.001 to 0.002
12	Retainer (cage) type of retention	Machined
13	Retainer (cage) bore to O.D. concentricity	0.002
14	Retainer (cage) land width (min. effective)	0.02
15	Retainer (cage) face to bearing face clearance	0.005

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14. ABSTRACT This document provides a model specification for the rework and/or repair of bearings used in aircraft engines, helicopter main power train transmissions, and auxiliary bearings determined to be critical by virtue of performance, function, or availability. The rolling-element bearings to be processed under the provisions of this model specification may be used bearings removed after service, unused bearings returned from the field, or certain rejected bearings returned for reinspection and salvage. In commercial and military aircraft application, it has been a practice that rolling-element bearings removed at maintenance or overhaul be reworked and returned to service. Depending on the extent of rework and based upon theoretical analysis, representative life factors (LF) for bearings subject to rework ranged from 0.87 to 0.99 the lives of new bearings. Based on bearing endurance data, 92 percent of the bearing sets that would be subject to rework would result in L_{10} lives equaling and/or exceeding that predicted for new bearings. The remaining 8 percent of the bearings have the potential to achieve the analytically predicted life of new bearings when one of the rings is replaced at rework. The potential savings from bearing rework varies from 53 to 82 percent of that of new bearings depending on the cost, size, and complexity of the bearing.					
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